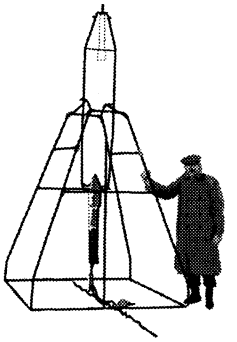
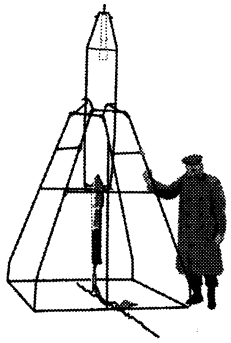


WETLIFE STUDY OF NICKEL HYDROGEN CELLS

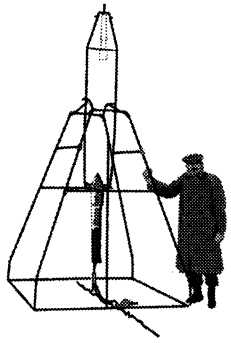
Gopalakrishna M. Rao
NASA/Goddard Space Flight Center
Power Systems Branch, Code 563
Greenbelt, MD 20771



Contents

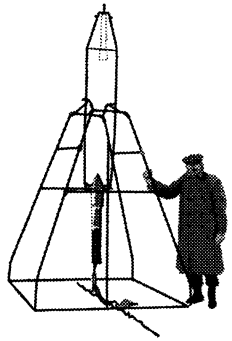
- Background
- Approach
- Destructive Physical Analyses (DPA)
- Gas Analyses and Nickel Precharge Determination
- Thermal Imaging
- Cycle Testing
- Summary
- Lead Team Members

Background

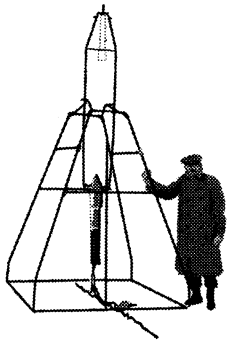


- Unplanned launch delays often results in use of batteries for NASA missions that exceeded the recommended wetlife of three (3) to five (5) years
  - Nickel-Cadmium (NiCd) up to seven (7) years (TDRS) and Nickel-Hydrogen (NiH2) up to six years (AQUA)
- Both Hubble Space Telescope (HST) and Space Station battery cells' wet life will exceed eight (8) years by the time of refurbishment
  - HST refurbishment is scheduled in August 2008
  - Battery cells made in 1996 (stored dry for four years) and activated in 2000
- A study is in progress to determine the residual Nickel Precharge, and to understand the Performance and Cycle Life of aged Nickel Hydrogen cells that were in cold storage up to thirteen (13) years

Approach



- Destructive Physical Analyses (DPA)
- Gas Analyses and Nickel Precharge Determination
- Thermal Imaging
- Life Cycle Testing

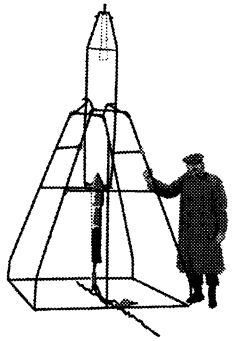


DPA

- A contract was awarded to Lockheed Martin/Comsat Technical Services in July 07
- Selected Terra 50 Ah (95), Space Station

  81 Ah (94, 98, 01 and 04), HST 90 Ah (00), US Govt. 90 Ah (95 and 97), Loral/SS 120 Ah (97, 00 and 06) and Aqua 160 Ah (97) cells;
- All cell were in cold storage and had minimum Acceptance Test Procedure (ATP) cycles

*numbers within ( ) are wet life age

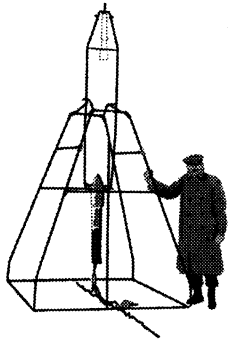


DPA - cont'd.

- Electrical Characterization
  - Capacities, Charge Retention, Impedance and Cell Reversal Tests completed, except 90 Ah (95) cell
  - Nominal performance with a small second plateau in older cells
  - All tested cells to date exhibited expected ~ -0.3 to -0.4 V reversal voltages except Space Station 81 Ah (94), HST 90 Ah (00), and Loral/SS 120 Ah (97) whose values more negative than -1.00 V
- Gas Chromatographic analysis did not show signature for gas(es) form the cells
- Cell Tear down, Plate, and electrolyte analyses are in progress

*numbers within ( ) are wet life age

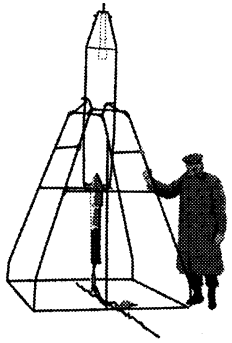
Gas Analyses and Nickel Precharge Determination



- A contract was awarded to Aerospace Corporation in July 07
- Selected Terra 50 Ah (95), Intelsat 50 Ah (95), Space Station 81 Ah (95, 00 and 04), HST 90 Ah (00), US Govt. 90 Ah (97), Loral/SS 120 Ah (97, 99 and 04) and Aqua 160 Ah (97) cells; *numbers within () are wet life age
- All cell were in cold storage and had minimum ATP cycles except Intelsat (95) that had 9 years of real-time Geosynchronous-Earth-Orbit (GEO) testing

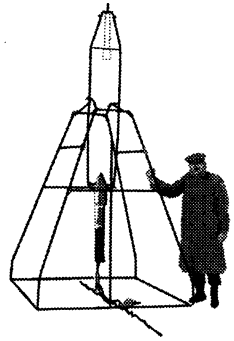
*numbers within ( ) are wet life age

Gas Analyses and Nickel Precharge Determination - contd.



- Electrical Characterization
  - Capacities, Charge Retention, Impedance and Cell Reversal Tests completed except for Space Station cells
  - Nominal performance with a small second plateau in older cells
  - All tested cells to date exhibited expected ~ -0.3 to -0.4 V reversal voltages except HST 90 Ah (00) and Loral/SS 120 Ah (99) with values more negative than -1 V, and Intelsat (95) with a value of -0.04 V
- Gas samples from the cells were collected under vacuum and then quantitatively analyzed using RGA (Residual Gas Analyzer - Mass Spectrometer)
  - No signature for gas(es), except the Intelsat 50 Ah (95) which was a hydrogen Precharge cell
- Cell Tear down and Plate analyses for Nickel Precharge determination are in progress

Thermal Imaging

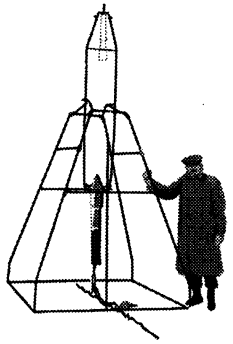


- Performed at Goddard Space Flight Center, Code 563 Battery Lab
- Selected US Govt. 90 Ah (95, 98, 00 and 04)
- All cell were in cold storage and had minimum ATP cycles
- Electrical Characterization

  - Capacities; nominal performance with a small second plateau in older cell but the cell activated in 98 had lowest capacity

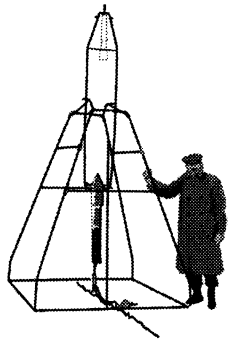
*numbers within () are wet life age

Thermal Imaging - cont'd.



- IR Camera was used to measure the Cell Surface Temperature during the charge/discharge cycles
  - Setting and description of the imaging testing was presented by J. Shue et.al. at 2004 NASA Aerospace Battery Workshop
  - Data analysis is in progress
  - Preliminary analysis indicates that older the cell greater the heat generation but cell over charge (capacity) could dominate heat generation

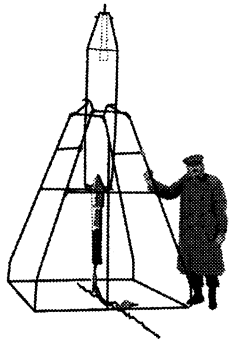
Cycle Testing



- Performed at Naval Surface Warfare Center, Crane
- Selected Five (5) Space Station 81 Ah (97), and US Govt. 90 Ah (97) cells
- All cell were in cold storage and had minimum ATP cycles

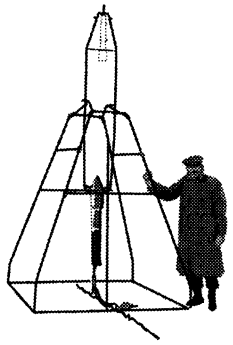
*numbers within ( ) are wet life age

Cycle Testing - cont'd.



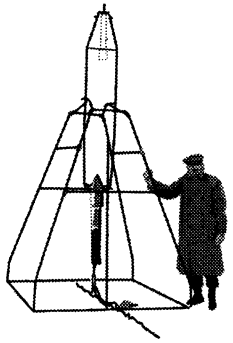
- Electrical Characterization
  - Capacities, Charge Retention, Impedance and Cell Reversal Tests completed
  - Nominal performance
  - Space Station cells and US Govt. cells exhibited expected about -0.3 to -0.4 V reversal voltages, respectively
- Stress test Profile
  - 60% Depth-of-Discharge, 10°C and 90 minutes orbit (60 minutes charge, 30 minutes discharge, VT clamp and 1.08 recharge ratio)
- US Govt cells: Completed 1150 nominal Low-Earth-Orbit (LEO) cycles
- Space Station cells: LEO cycling just started

Summary

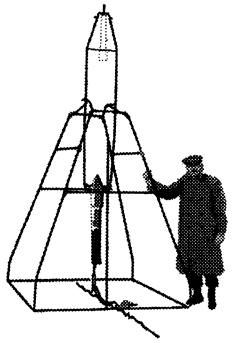


- A study was undertaken to determine the residual Nickel Precharge, and to understand the Performance and Cycle Life of Aged Nickel Hydrogen cells that were in cold storage up to thirteen (13) years
- Comsat Technical Services, Aerospace Corporation, and NSWC/Crane test data to date indicate a nominal electrical performance with a small second plateau and the presence of Nickel Precharge in the cells
  - Cell Teardown, Plate (active Nickel Precharge determination), and Electrolyte Analyses are in progress
- Preliminary Thermal Imaging data indicates that older the cell greater the heat generation, but cell over charge (capacity) could dominate heat generation
- US Govt cells has completed 1150 nominal 60% LEO cycles
- The completion date for this study is January 31, 2008

Lead Team Members



- DPA: Dr. Hari Vaidyanathan, Lockheed Martin/Comsat Technical Services
- Gas Analyses and Nickel Precharge Determination: Dr. Albert Zimmerman, Aerospace Corporation
- Thermal Imaging: Mr. Jack Shue, Goddard Space Flight Center
- Cycle Testing: Mr. Harry Brown, Naval Surface Warfare Center, Crane



Acknowledgment

- Mr. J. Armantrout and R. Hollandsworth from Lockheed Martin for providing US Govt. 90 Ah cells
- Mr. D. DeBiccari from Loral/SS for providing commercial 120 Ah cells
- MS. P. Dalton from NASA/GRC for coordinating to obtain ISS 81 Ah cells